2.4 SIGNATURE FLUCTUATIONS

The echo signal amplitude from a complex target in motion varies continually because of variations in the meteorological conditions, the lobe structure of the antenna pattern, equipment instabilities, or variations in the target radar cross section. The latter, when it involves complex targets (the typical target of interest to radars), is extremely sensitive to the aspect from which the radar is observing. Therefore, as the target aspect changes even slightly relative to the radar, variations in the echo signal will result. Fluctuations in the received target signal amplitude impact the radar's ability to detect and track targets.

Although radar detection thresholds typically are calculated as the signal-to-noise ratio (S/N) required to detect a single pulse, actual target detection occurs as the group of pulses in the observation period is integrated in some manner. Variation in the received target signal amplitude during the observation period has the effect of noise and causes a degradation in the integrated signal, resulting in an increase in the threshold required for target detection. The fluctuation (or noise) in the received target signal amplitude due to the changes in radar cross section, that result from changes in the viewing angle, is called scintillation or "amplitude noise."

Signal fluctuations also affect target angle and range tracking. A complex target can be envisioned as a set of scatterers with an apparent centroid that depends on the relative locations and efficiency of each scatterer. Signal fluctuation causes movement of this apparent centroid, resulting in movement of the target tracking point. This phenomenon is known as glint or "angle noise." Random distributions around the target centroid have been proposed as reasonable methods of describing the glint.

For target detection, proper accounting for target cross section variations involves use of a probability density function and the correlation properties with respect to time for a particular target and type of trajectory. The procedure to find the correct density function and autocorrelation function requires an immense amount of data for each target and radar type. Usually, this is not practical. An economical alternative to assessing the effects of varying cross section is to postulate a reasonable model for variations and associated signal amplitude fluctuations, and analyze this information mathematically. Several types of probability distributions have been proposed as reasonable models for echo signal fluctuations. Among these are the chi-square family, the log-normal family, the Swerling models, the Weinstock models, and the non-fluctuating model. Most of these models have been shown to match (approximately) some empirical data sets, but no general theory of signal amplitude fluctuations exists.

The non-fluctuating case models a perfectly steady target echo. This is not realistic for real radar targets, except in special cases such as spheres or targets that are stationary over the observation time. However, this model could be used to give detection estimates when minimal target cross section information is available.

Swerling case 1 models a complex target consisting of many independent scatterers of approximately equal echoing areas. This model assumes that the echo pulses received from a target on any one scan are of constant amplitude throughout the scan but are independent (uncorrelated) from scan to scan. This assumption ignores the effect of the antenna beam shape on the echo amplitude. An echo fluctuation of this type is called scan-to-scan fluctuation. Swerling case 2 models the same type of target as case 1. However, case 2 assumes that the fluctuations are more rapid than in case 1 and are independent from pulse to pulse.

Swerling case 3 models a target that can be represented as one large reflector combined with other smaller reflectors. The fluctuations are assumed to be independent from scan to scan as in case 1. Swerling case 4 models the same type of target as case 3, but with more rapid fluctuations that are independent from pulse to pulse (as in case 2).

The Swerling fluctuation models are special cases of chi-square distributions. Cases 1 and 2 are of degree two and are called the Rayleigh-power or exponential distributions. Cases 3 and 4 are chi-square of degree four.

General chi-square distributions also can be used to model signature fluctuations. Analysis of test measurements of an aircraft flying straight and level courses show that fluctuations can usually be well fitted by chi-square distributions with degrees ranging from 1.8 to 4. Although the chi-square distributions with degrees other than two or four have fit empirical data, the models generally are not based on a physical scattering mechanism.

One case where a physical connection to a different chi-square model has been shown is the Weinstock distribution. This is a chi-square distribution of degree less than two. Weinstock showed that this distribution can describe certain simple shapes, such as cylinders or cylinders with fins.

Log-normal distributions have been used to model scattering from highly directive reflectors when viewed from random aspects. Examples include randomly oriented flat plates, corner reflectors, and antennas. Ship cross sections also have been modeled in this way. Most of this modeling has been based on empirical rather than theoretical considerations.

Few, if any, real targets precisely fit any of these distributions. Even if the exact statistical distribution of a targetõs reflections were known, the actual radar measurement on a particular flight path might not clearly relate to that distribution. The Signature Fluctuations Functional Element is intended to generate statistical changes in target signal returns that are generally accepted as realistic, and to simulate the effects of these changes on radar detection and tracking performance.

ESAMS provides options to address the scintillation effect by using Swerling's cases 1 and 2, the chi-square distribution that corresponds to the exponential distribution, or cases 3 and 4, the chi-square distribution of the fourth degree. Glint is addressed by using a function that produces Gaussian random numbers with specified mean and standard deviation "appropriate" to the correlated glint.

2.4.1 Functional Element Design Requirements

This section contains the design requirements to implement the simulation of signature fluctuations.

a. ESAMS will simulate the alteration of the target RCS due to scintillation effects, which affects the target detection capability of the radar.

The magnitude of the alteration will be determined through either an exponential or chi-squared draw using the RCS value as the mean. The altered RCS value will subsequently be adjusted through a time-correlation routine that considers both the latest (current) and most-recent RCS value, and the time interval.

b. ESAMS will simulate the angle noise (glint), which causes a change with time in the apparent location of the target with respect to a reference point on the target.

The impact of the corruptive effects of correlated glint will be determined by establishing the apparent target location. The program will determine a half-power glint frequency, based on effective target dimensions, in elevation and azimuth, and target angular rate of change. From this, correlated glint errors will be determined, again in elevation and azimuth, and subsequently, the "corrupted" elevation and azimuth will be calculated.

2.4.2 Functional Element Design Approach

This section describes the design approach that satisfies the requirements specified in the previous section. A design element is an algorithm that represents a specific component of the FE design.

2.4.2.1 Glint

The design requirements for glint are addressed by using a stochastic representation of the phenomenon to find the apparent location of the target. Glint is modeled as a correlated Gaussian process, where the standard deviation is one-fourth of the target angular size, and the correlation coefficient is given by an exponential decay in time. The time constant of the correlation coefficient is proportional to the aspect rate of change of the target.

The design approach consists primarily of determinations of location and rate of change of the target with respect to the radar and the effective target length, the glint half-power frequency, the correlated glint errors, and the "corrupted" target position.

Design Element 4-1: Geometry

This portion of the design addresses the range between radar and target, the relative location geometry of radar and target, the target azimuth and elevation aspect and its rate of change, and the effective target dimensions. All these will directly impact the magnitude of the angle noise.

The following algorithms are used to represent the target position relative to the site in the inertial coordinate system (ICS).

$$X_{TS} = X_T - X_S$$

$$Y_{TS} = Y_T - Y_S$$

$$Z_{TS} = Z_T - Z_S$$

$$R_{TS} = \sqrt{X_{TS}^2 + Y_{TS}^2 + Z_{TS}^2} \qquad [2.4\text{-}1]$$

where	X_T, Y_T , and Z_T	=	actual target X, Y, and Z coordinates
	X_S, Y_S, and Z_S	=	site X, Y, and Z coordinates
	X_{TS}, Y_{TS}, and Z_{TS}	=	distance from site to target in X, Y, and Z components
	R_{TS}	=	range from site to target in X, Y, and Z components

The following algorithms represent the range from the target to the site in the body coordinate system (BCS). This conversion to body coordinates was necessary to determine the elevation and azimuth angles between the target and the line-of-sight (LOS).

$$R_{xy} = \sqrt{X_b^2 + Y_b^2}$$

$$R_{xyz} = \sqrt{X_b^2 + Y_b^2 + Z_b^2}$$

$$\theta = \left| arccos \frac{Z_b}{R_{xyz}} \right| \qquad [2.4\text{-}2]$$

$$\varphi = \left| arccos \frac{X_b}{R_{xy}} \right|$$

where	X_b, Y_b, and Z_b	=	X_{TS}, Y_{TS}, and Z_{TS} coordinates converted into BCS
	R_{xy} and R_{xyz}	=	range from the site to the target in x, y, and z components
	θ	=	elevation angle between the target and the LOS (BCS) Note: Polar angle measured from the Z-axis
	φ	=	azimuth angle (BCS)

The algorithms that follow are used to calculate the angular rates of change.

$$\dot{\theta} = \frac{\theta_c - \theta_o}{T_S} \qquad [2.4\text{-}3]$$

$$\dot{\varphi} = \frac{\varphi_c - \varphi_o}{T_S}$$

where	and	=	angular rates of change (elevation and azimuth, respectively)
	θ_c and φ_c	=	current angle values (elevation and azimuth, respectively)
	θ_o and φ_o	=	previous (old) angle values (elevation and azimuth respectively)
	T_S	=	simulation time step

Lastly, the effective target dimensions are then calculated using the following algorithms.

$$L_{W_y} = L_W|\cos\varphi \cos\theta|$$

$$L_{B_y} = L_B|\sin\varphi \sin\theta|$$

$$L_{W_p} = L_W|\sin\varphi \cos\theta|$$

$$L_{B_p} = L_B|\cos\varphi \cos\theta| \qquad [2.4\text{-}4]$$

$$L_{E_y} = \max\left(L_{W_y}, L_{B_y}\right)$$

$$L_{E_p} = \max\left(L_{W_p}, L_{B_p}\right)$$

where
$L_{W_{y,p}}$ = wing length in yaw and pitch
$L_{B_{y,p}}$ = body length in yaw and pitch
$L_{W,B}$ = wing and body length, respectively
$L_{E_{y,p}}$ = effective target length (yaw and pitch), respectively

The purpose of the geometry calculation is to determine the effective target length in azimuth (yaw) and elevation (pitch). (Note: remember this is for level flight only). These values, plus the target aspect rate of change (in azimuth and elevation) are subsequently used to calculate the glint half power frequency. This is subsequently used to calculate the correlation coefficient of glint.

Design Element 4-2: Glint Half-Power Frequency

This design element calculates the dependency of the target rotation on glint. This dependency is known as the half-power frequency (Reference 10, Equation 3.3.6, p. 114) in azimuth (yaw) and elevation (pitch). Once these values are calculated, they are checked to be no less than a specified value

$$\omega_{g_y} = \left|\frac{4\pi\varphi_r L_{E_y}}{\lambda}\right|$$

$$[2.4\text{-}5]$$

$$\omega_{g_p} = \left|\frac{4\pi\theta_r L_{E_p}}{\lambda}\right|$$

where
ω_{g_y, g_p} = half-power power frequency in azimuth (yaw) and elevation (pitch)
λ = radar wavelength

Design Element 4-3: Glint Error and Target Position

This glint error at a particular time depends on both the previous glint error and an independent random draw. The first step is the calculation of standard deviation of uncorrelated glint error. The standard deviation of uncorrected glint error is based on the effective target length, both in pitch and yaw (Reference 10, pg 116-118). It is calculated as follows:

$$\sigma_g = \frac{L_E}{4R_{TS}} \qquad [2.4\text{-}6]$$

where σ_g = standard deviation of uncorrelated glint error
L_E = effective target length
R_{TS} = range from site to target in ICS

The multiplier value of .25 is at the upper range of that specified for aircraft (0.16 to 0.25); a value of .33 is specified for uniform scatterers and .238 for triangular scatterers.

The correlated glint error depends on this uncorrelated value and on the correlation coefficient of glint (ρ_g), computed as follows:

$$\rho_g = e^{-\omega_g T_g} \qquad [2.4\text{-}7]$$

where ω_g = power frequency
T_g = glint time step, since last call

The standard deviation of correlated glint is then found by the following algorithm:

$$\sigma_c = \sigma_g \sqrt{1 - \rho_g^2} \qquad [2.4\text{-}8]$$

Finally, the correlated glint error is calculated as follows:

$$\delta_c = \rho_g \delta_0 + \eta \sigma_c \qquad [2.4\text{-}9]$$

where η = random number (M = 0 & σ = 1)
δ_c = correlated glint error
δ_0 = previous correlated glint error

Independently, the actual target azimuth and elevation are determined using the following algorithms:

$$\varphi_a = arctan\left(\frac{Y_{TS}}{X_{TS}}\right), \quad X_{TS} \neq 0$$

$$\begin{cases} \theta_e = arctan\left(\dfrac{Z_{TS}}{\sqrt{X_{TS}^2 + Y_{TS}^2}}\right), & X_{TS} \neq 0 \text{ and } Y_{TS} \neq 0 \\ \theta_e = \dfrac{\pi}{2}, & X_{TS} = 0 \text{ and } Y_{TS} = 0 \end{cases} \qquad [2.4\text{-}10]$$

Glint corrupted Azimuth and Elevation is computed as follows:

$$\begin{aligned} \varphi_c &= \varphi_a + \delta_y \\ \theta_c &= \theta_e + \delta_p \end{aligned} \qquad [2.4\text{-}11]$$

where $\delta_{y,\,p} = \delta_c$ (in yaw and pitch)

If the situation arises where the effective target length in yaw and pitch, adjusted for distance, exceeds the radarõs field-of-view, the respective glint error in yaw or pitch is set to zero.

The apparent target position is then converted to rectangular as follows:

$$\begin{aligned} X_{T_{app}} &= R_{TS} \cos\varphi_c \cos\theta_c + X_S \\ Y_{T_{app}} &= R_{TS} \sin\varphi_c \cos\theta_c + Y_S \\ Z_{T_{app}} &= R_{TS} \sin\theta_c + Z_S \end{aligned} \qquad [2.4\text{-}12]$$

2.4.2.2 Scintillation Effects

To simulate the amplitude noise effects, the model will alter the RCS value per one of two possible scintillation equations.

To satisfy the design requirements related to scintillation or "amplitude noise," a modified RCS will be calculated through the use of either an exponential or chi-squared to the fourth power draw, using the current RCS value as the mean; the calculated RCS will subsequently be time correlated.

Design Element 4-4: Exponential Draw

A negative-exponential distribution provides an acceptable representation of the situation where the target consists of a large number of scattering elements of which no single one is (or a few are) predominant, and where the phase and/or amplitude variations of the individual scatterers are statistically independent of all the others (i.e., they are not correlated). The voltage that is induced in the receiving antenna can be represented as the sum of two statistically independent and quadrature-phased RF voltages whose joint probability density function is gaussian (normal). The distribution of the voltage at the receiver input results in a Rayleigh distribution of the detected (linearly rectified) output voltage of the receiver. An example of such a target (also referred to as Rayleigh target) is a large aircraft, viewed at microwave frequencies and at aspect angles where there is no predominant specular reflection from a large surface (Reference 22, page 116).

Probability of detection is equal to the integral of the probability density function $\rho(\sigma)$ of the RCS for the RCS range of values from minimum detectable target cross section to infinity.

The exponential draw is calculated as follows:

$$\sigma_s = -\sigma \log_e \eta \tag{2.4-13}$$

where
σ_s = RCS value of target corrected for scintillation effects
σ = RCS value of target
η = random number

Design Element 4-5: Chi-square with Four Degrees of Freedom Draw

A chi-square distribution with 4-degrees of freedom provides an acceptable representation of random aspect variations of a moving target whose aspect pattern is similar to ones that are obtained for aircraft that has one dominant scattering element plus a number of smaller scatterers (Reference 22, page 117). The chi-square draw is calculated using Box-Mullerõs transformation (Reference 23, pg 453.)

$$\begin{aligned}
\xi_1 &= \sqrt{\frac{\sigma}{4}\left(-2\log_e \eta_1\right)} \cos 2\pi\eta_2 \\
\xi_2 &= \sqrt{\frac{\sigma}{4}\left(-2\log_e \eta_1\right)} \sin 2\pi\eta_2 \\
\xi_3 &= \sqrt{\frac{\sigma}{4}\left(-2\log_e \eta_3\right)} \cos 2\pi\eta_4 \\
\xi_4 &= \sqrt{\frac{\sigma}{4}\left(-2\log_e \eta_3\right)} \sin 2\pi\eta_4
\end{aligned} \tag{2.4-14}$$

where
σ = RCS value of target
η_i = random number, i = 1 - 4
ξ_i = Gaussian draw, i = 1 - 4

The RCS value adjusted for scintillation is then calculated by summing the square of individual draws as follows:

$$\sigma_s = \xi_1^2 + \xi_2^2 + \xi_3^2 + \xi_4^2 \tag{2.4-15}$$

where σ_s = RCS value (chi-square) adjusted for scintillation effects

Design Element 4-6: Time Correlation

A correlation coefficient of scintillation (ρ_s) will be used to find a weighted average (σ_w) of the calculated (current) scintillation-corrupted RCS and the previous correlated scintillation-corrected RCS value.

$$\rho_s = e^{-\frac{T_p - T_o}{T_c}} \qquad [2.4\text{-}16]$$

where T_p = present time
T_o = old time
T_c = correlation time

The weighted average is the computed from:

$$\sigma_w = \rho_s \sigma_o + (1 - \rho_s)\sigma_p \qquad [2.4\text{-}17]$$

where σ_w = weighted new correlated RCS value
ρ_s = correlation coefficient
σ_o = old RCS value
σ_p = present RCS value

2.4.3 Functional Element Software Design

This section describes the software design necessary to implement the functional element requirements and the design approach outlined above. Section 2.4.3 is organized as follows: the first part describes the subroutine hierarchy and gives descriptions of the relevant subroutines; the next three parts contain logical flow charts and describe all important operations represented by each block in the charts; the last part contains a description of all input and output data for the functional element as a whole and for each subroutine which implements fluctuations.

Fluctuations Subroutine Design

The FORTRAN call tree for the Fluctuations functional element in the ESAMS 2.6.2 source code is shown in Figure 2.4-1. The diagram depicts the entire model's structure for this FE, from ZINGER (the main program) through the least significant subroutine in the FE. Subroutines which directly implement the functional element appear as shaded blocks. Subroutines which use or contribute to functional element results appear with a shadow. Each of these subroutines is briefly described in Table 2.4-1.

TABLE 2.4-1. Signature Fluctuations Subroutine Descriptions.

MODULE NAME	DESCRIPTION
ATAN3	Calculates the arc tangent of y/x in range 0 to 2.
CHIDRW	Performs a chi squared to the fourth degree draw, using the RCS as the mean.
COREL8	Correlates a value with a previous value using the previous time, current time, and the correlation time from the common block PROGC.
EXPDRW	Takes the mean value passed in as an argument, and computes the exponential draw.
GAUSS	Generates normally (i.e., Gaussian) distributed random numbers.
GLINT	Calculates glint noise to find apparent target position.
GYRATE	Computes an attitude matrix for a coordinate transformation, decides the direction of the transformation, and does a matrix multiply to execute the transformation.
RADEV	Returns a Gaussian distributed random number with standard deviation sigma.
SINTL8	Alters the RCS value to simulate the scintillation effect by calling on the desired probability density function.
TGTRCS	Returns target RCS for input geometry.
UNIRAN	Generates uniform random numbers.

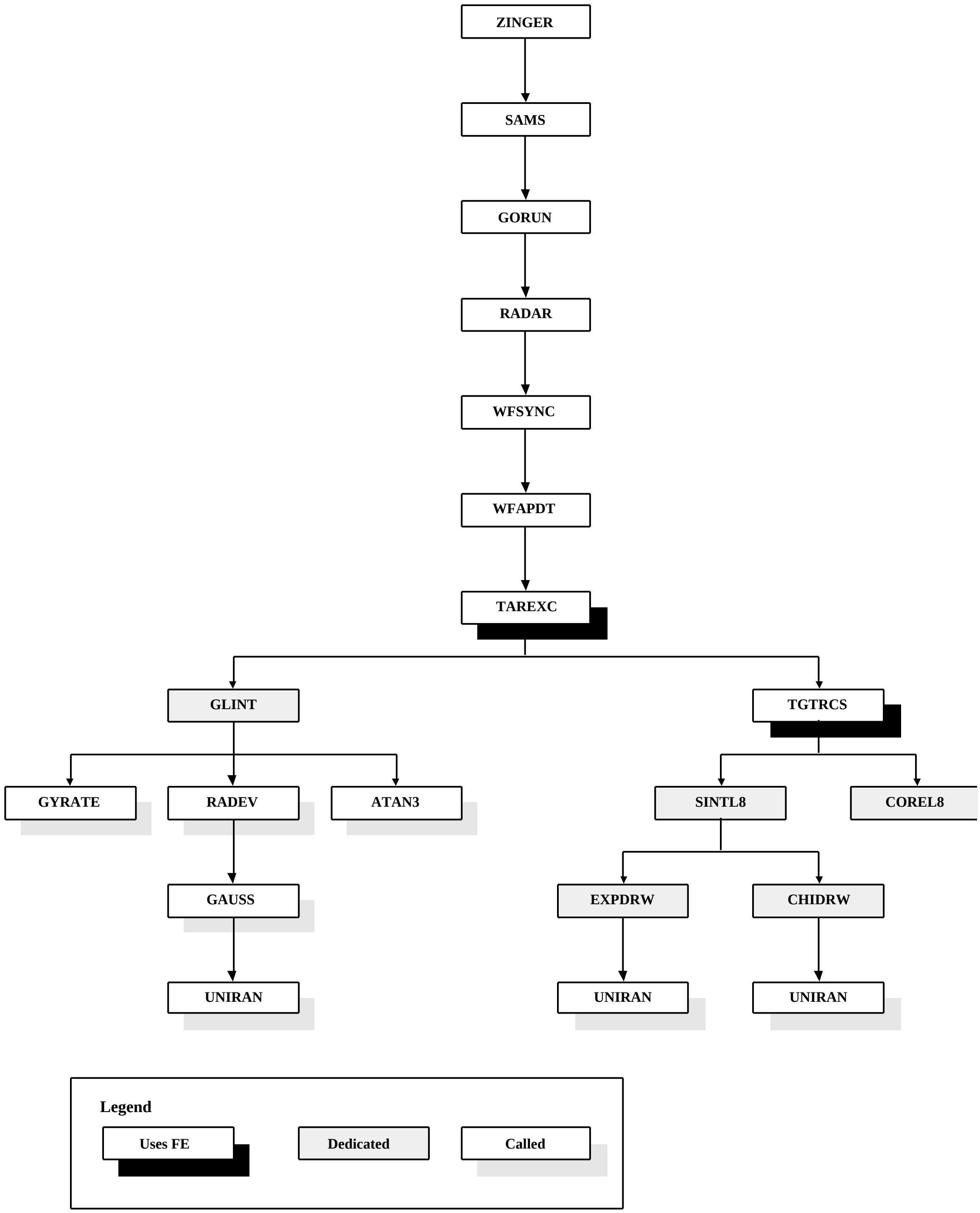

FIGURE 2.4-1. Fluctuations (GLINT and Scintillation) Subroutine Call Hierarchy.

Functional Flow Diagram for GLINT

Figure 2.4-2 shows the logical flow for the GLINT implementation of signature fluctuations. Subroutine names appear in parentheses at the bottom of each process block.

Every call to Subroutine RADEV involves a call to GAUSS which inherently calls UNIRAN. The numbered blocks in the flow diagram are discussed below.

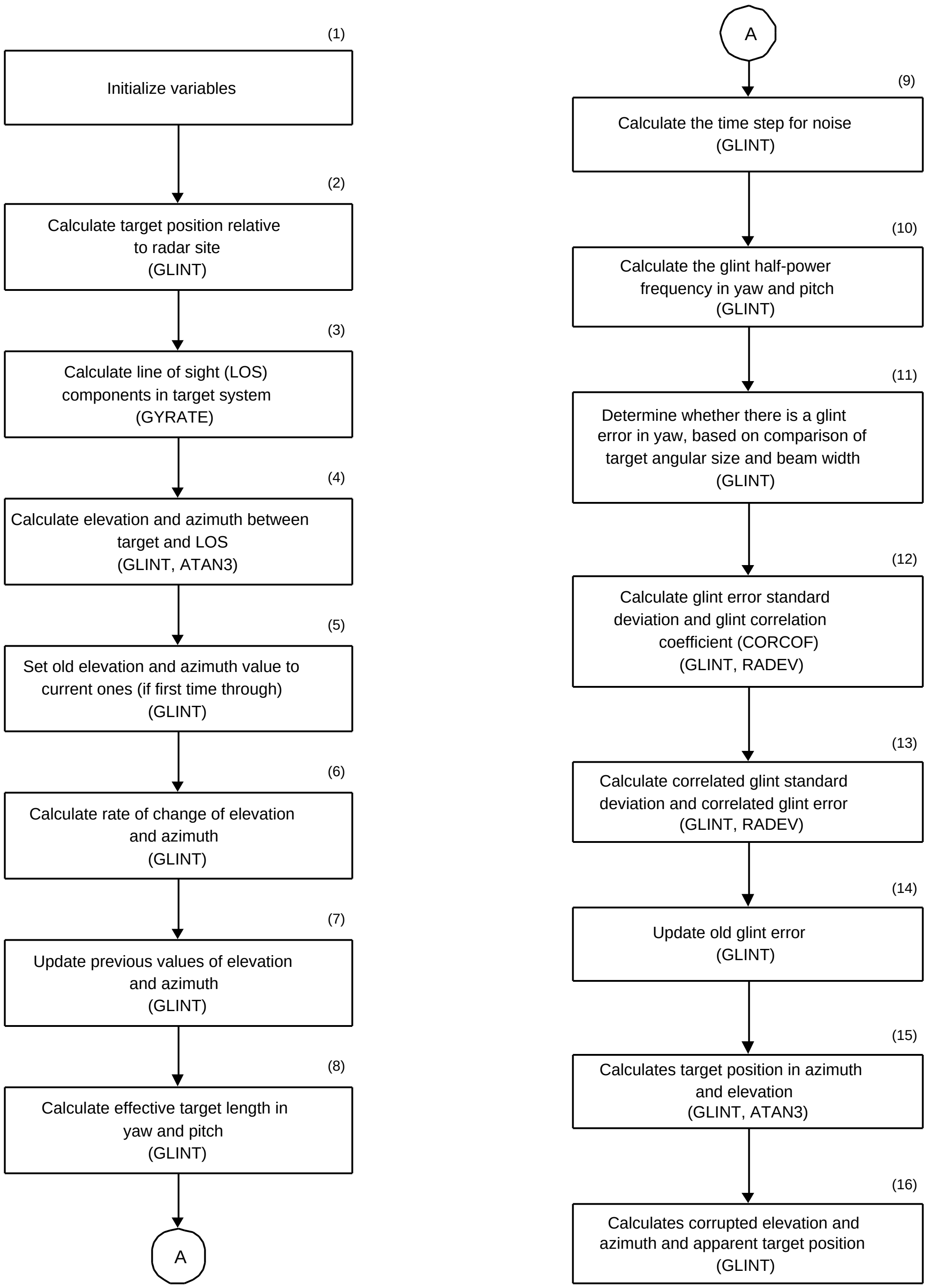

FIGURE 2.4-2. GLINT Functional Flow Diagram.

Subroutine GLINT calculates the corruption effects of correlated glint noise to determine an apparent target position. Glint is actuated by setting the IGLINT flag for the radar of interest to one. The magnitude of the glint error is based on effective body length values in yaw (i.e., azimuth) and pitch (i.e., elevation).

Block 1. Initializes the values for previous glint error in yaw (azimuth) (GLNTWY) and pitch (elevation) (GLNTWP) equal to zero, and initializes the values for glint half-power frequency in yaw (GHPWRY) and pitch (GHPWRP) equal to zero.

Block 2. Calculates the target position relative to the radar site using equation set [2.4-1]. Values in x, y and z equal the respective target coordinates minus the site coordinates (the z value for the radar equals the z value of the tracking antenna in ICS) .

Block 3. Calculates components of the line-of-sight (LOS) in the target (or body) coordinate system using R_{xy} and R_{xyz} of equation [2.4-2]. Calls on the GYRATE utility routine with an input of target location (block 3), and the current target roll, yaw and pitch angle. The transformation routine returns values for XTGT, YTGT, and ZTGT.

Block 4. Calculates an elevation angle between the target and the line-of-sight using equation [2.4-2]. The routine consists of a calculation of the range of the target to the site (R) and subsequently the arc cosine of Z/R. Calculates the azimuth angle between the target longitudinal axis and the LOS using equation [2.4-2]. If the target is not perceived as immediately over the radar (azimuth in that case is set at zero), the azimuth angle equals the arc cosine of the x component of range divided by the range in the x-y plane.

Block 5. Sets values of old elevation and azimuth angles equal to the current ones, if this is the first time through Subroutine GLINT.

Block 6. Calculates the rate of change of the azimuth and elevation angles, by dividing the changes in angle values by the simulation time step (variable - GDT) using equation [2.4-3].

Block 7. The old elevation and azimuth values are updated.

Block 8. Calculates the effective target length in yaw and pitch using equation [2.4-4]. Step 1 (for the yaw case) is to multiply the wing length by the cos(azim) and sin(elev), and multiply the body length by the sin(azim) and sin(elev). Step 2 is to select the larger of the two values for the effective body length. For the pitch aspect, in step 1 the wing length is multiplied by sin(azim) and cos(elev) and the body length is multiplied by cos(azim) and cos(elev). In step 2, the larger of the two is selected to be the effective body length.

Note: the reference "The Question of Elengy," BDM/ABQ-86-1265-WP, July 31, 1986, states that TAC ZINGER calculated wing and body length this way (as in 2.6.2), but that ESAMS did not include the sine-elevation cofactor (for the azimuth projection). This is different than what is in the 2.6.2 code (latest update Nov 1985). The white paper states that the ESAMS version of the equations should be favored and are correct for straight and level targets.

Block 9. Calculates the time step for glint (variable DTN) that will be used later in the calculation of the correlation coefficient of glint. The value is half of the simulation time step value (GDT) that was used Block 6

Block 10. Calculates the glint half-power frequency in the azimuth (yaw) and elevation (pitch) direction (GHPWRY and GHPWRP) using equation [2.4-5]. A check is subsequently made to select a value for the half-power frequency that is no less than a specified minimum line value.

Block 11. Sets the field of view, depending on the input that specifies a circular or noncircular radar beam, defines the radar half-power beam width and then checks to see how the target angular size in yaw compares with this beam width. If target size is greater, the assumption is that there is no glint error. Otherwise, the program continues with the calculation of the magnitude of the error.

Block 12. Calculates the standard deviation of glint error in yaw (azimuth) using equation [2.4-6]. Computes the correlation coefficient of glint using equation [2.4-7]. Subsequent to the calculation, a check is made to see if the correlation coefficient is very small (less than epsilon), in which case it is set to zero.

Block 13. Calculates a standard deviation of correlated glint using equation [2.4-8]. Computes the correlated glint error using equation [2.4-9].

Block 14. Updates the previous glint error value.

Blocks 12 through 14 are repeated for pitch (elevation).

Block 15. Calculates target position in azimuth and elevation, with respect to the radar, using equation [2.4-10]. If both x and y coordinates are equal to zero, the target is assumed to be overhead, and the elevation is equal to

Block 16. Calculates corrupted elevation and azimuth position by adding the target position to the error using equation [2.4-11], and calculates the rectangular coordinates of the apparent target position using equation [2.4-12].

Functional Flow Diagram for Scintillation

Figure 2.4-3 shows the logical flow for the scintillation implementation of signature fluctuations. Subroutine names appear in parentheses at the bottom of each process block. The numbered blocks in the flow chart are discussed below.

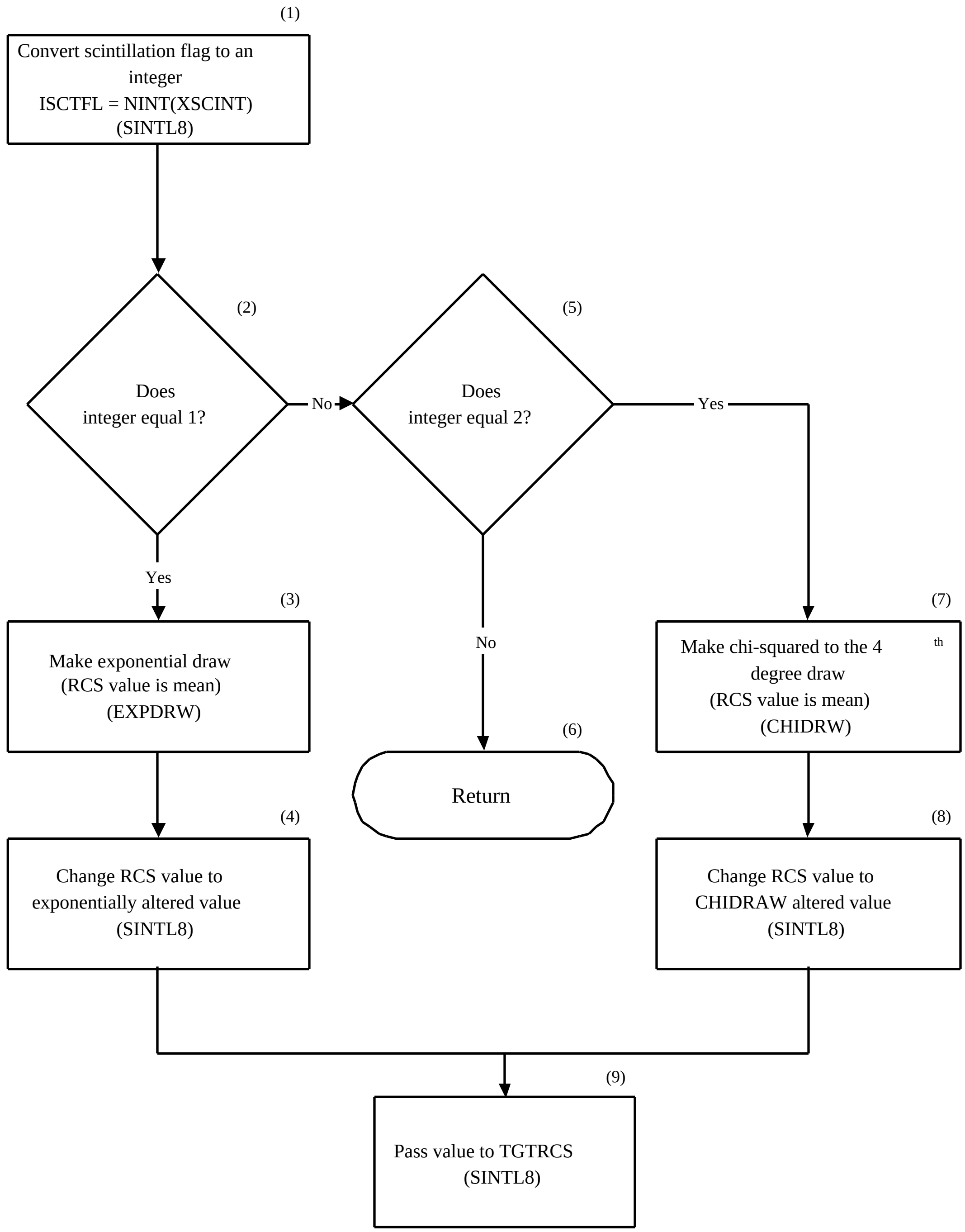

FIGURE 2.4-3. Scintillation Functional Flow Diagram.

Scintillation is actuated in the ESAMS input by setting the XSCINT flag to integer values of either one or two to specify the particular model of scintillation. SINTL8 alters the RCS values according to a draw that the user selects to represent the scintillation effects.

Block 1. Converts scintillation input (flag) to an integer.

Block 2. Checks to see if input directs an exponential draw (integer = 1).

Block 3. Directs an exponential draw, through the EXPDRW routine, using the RCS value as the mean. The EXPDRW routine consists of drawing a random number from 0 to 1 (using the UNIRAN routine), taking the RCS value as mean value, and computing the exponential draw using equation [2.4-13].

Block 4. Changes RCS value to an exponentially-altered RCS value.

Block 5. Checks to see if input directs a chi-squared draw (integer = 2).

Block 6. If input fails both checks, return.

Block 7. Chi-squared to the fourth degree draw (integer equal to 2) checks to see if input directs a chi-squared to the fourth degree draw, using the RCS value as the mean. The CHIDRW routine calculates two sets of Gaussian draws, based on the RCS value and two sets of uniform random numbers from 0 to 1 using equation [2.4-14]. This is repeated with the second set of random numbers, completing the last two algorithms in equation [2.4-14]. The draw is then calculated using equation [2.4-15].

Block 8. Changes RCS value to a chi-squared to the fourth degree-altered RCS value.

Block 9. Depending on the selected scintillation mode, a revised RCS value is passed to TGTRCS.

Functional Flow Diagram (Correlation)

Figure 2.4-4 shows the logical flow for the correlation implementation of signature fluctuations. The numbered blocks in the flow chart are discussed below.

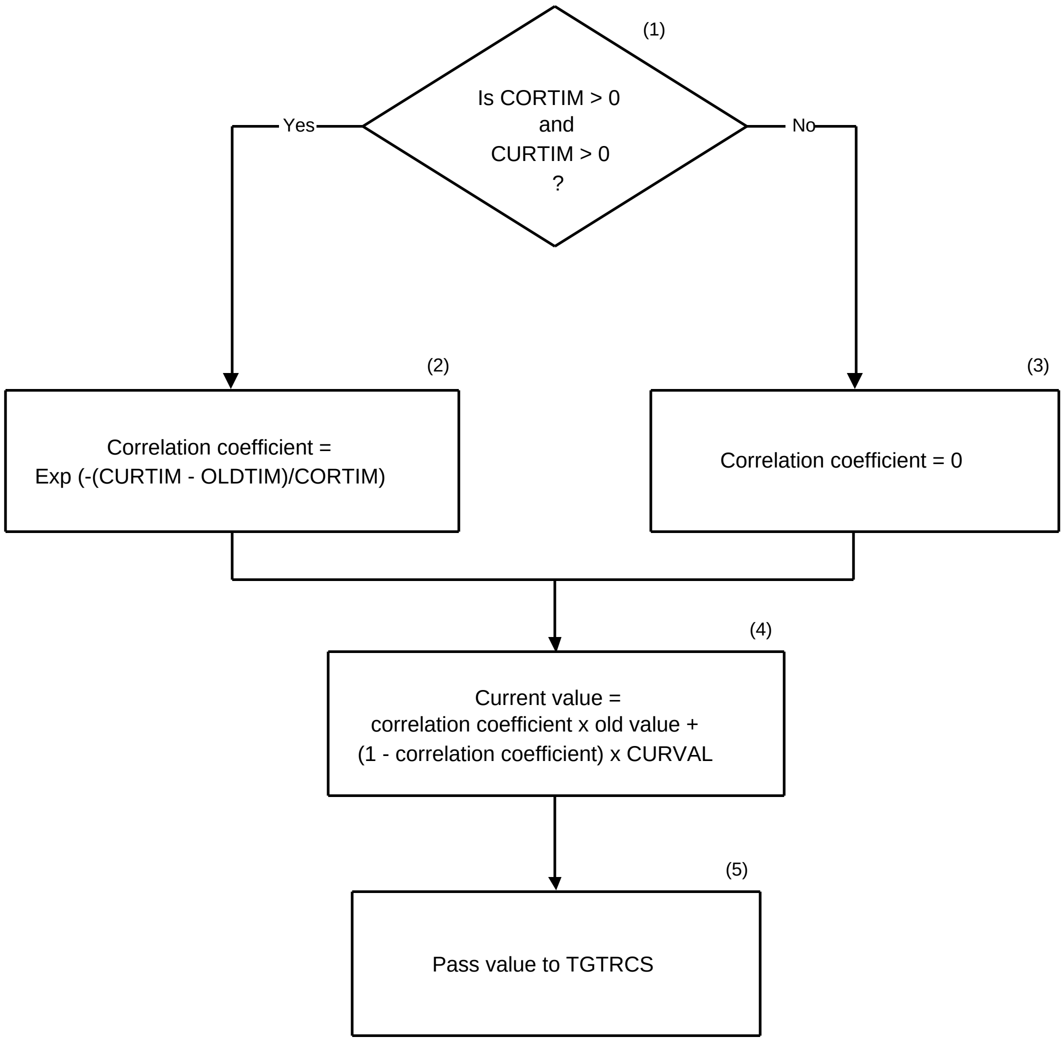

FIGURE 2.4-4. Correlation Functional Flow Diagram.

Provision is made for applying a correlation effect to the scintillation-corrupted target RCS by setting the control variable CORTIM to the chosen correlation time parameter, a value greater than zero. COREL8 correlates a new value to the previous value. There are no calls to other subroutines to perform correlation.

Blocks 1-3. Checks to see if correlation time (time increment) is greater than zero, and if the current time is greater than the "old time." If both are greater than zero, a correlation coefficient is calculated using equation [2.4-16]. If correlation time is less than, or equal, to zero (or current time is equal to old time), the correlation coefficient is set at zero.

Block 4. Calculates the new correlated value using equation [2.4-17].

Block 5. Passes the correlated RCS value to TGTRCS.

GLINT Input and Output Data

Tables 2.4-2 through 2.4-11 summarize the input and output variables for each of the subroutines listed in Table 2.4-1 that implement the signature fluctuations design.

TABLE 2.4-2. Input-Output Variables for Subroutine GLINT.

SUBROUTINE: GLINT

Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
ITAR	Argument	Number of target being processed	XTGAPP YTGAPP ZTGAPP	Argument	Apparent Target X, Y, and Z Coordinates
XTGIN YTGIN ZTGIN	Argument	Actual Target X, Y, and Z Coordinates			
PHITG PSITG THETTG	Argument	Roll, Yaw, and Pitch Angles			
IRADFL	Common 'FLAGS'	RADAR type flag, 1=ACQ, 2=TRK, 3=SKR, 4=ILL			
KFIRST	Common 'FLAGS'	Initialization Variable, first time through subroutine			
HPANG	Common 'FREND'	Half-power Angle			
HPOWER	Common 'FREND'	Half-power Angle of noncircular target			
ICIRC	Common 'FREND'	Flag, 0=Circular, 1=Noncircular Beam Cross Section			
GDT	Common 'GRADAR'	Simulation Time Step or System Time Increment (Sec)			
WVLTX	Common 'GRADAR'	Wavelength of GRADAR Transmitter			
XSJ YSJ ZSJ	Common 'RUNVR'	Site X, Y, and Z coordinate in ICS			
FOVRAD	Common 'RUNVR'	RADAR Field of View (Radians)			
BLENG	Common 'TGTV'	Target Body Length (m)			
WLENG	Common 'TGTV'	Target Wing Length (m)			

TABLE 2.4-3. Input-Output Variables for Subroutine GYRATE.

SUBROUTINE: GYRATE					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
X1 Y1 Z1	Argument	Original system coordinates (inertial or body)	X2 Y2 Z2	Argument	Transformed system coordinates (inertial or body)
ROLL YAW PITCH	Argument	Euler Angles relating the systems			
IWAY	Argument	Indicates direction of coordinate transformation			

TABLE 2.4-4. Input-Output Variables for Function RADEV.

FUNCTION: RADEV					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
SIGMA	Argument	Desired standard deviation of output number	RADEV	Argument	Random number with mean of 0 and standard deviation sigma

TABLE 2.4-5. Input-Output Variables for Function GAUSS.

FUNCTION: GAUSS					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
DEVIAT	Argument	Deviation in Random Values	GAUSS	Argument	Standard normal random number
EXPECT	Argument	Expected Value			

TABLE 2.4-6. Input-Output Variables for Function UNIRAN.

FUNCTION: UNIRAN					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
DUMMY	Argument	Dummy variable	UNIRAN	Argument	Real random number

TABLE 2.4-7. Input-Output Variables for Function ATAN3.

FUNCTION: ATAN3					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
X	Argument	Number proportional to cosine of angle	ATAN3	Argument	Calculates the arc tangent of Y/X from 0 to 2π
Y	Argument	Number proportional to sine of angle			

TABLE 2.4-8. Input-Output Variables for Subroutine SINTL8.

SUBROUTINE: SINTL8					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
RCSVAL	Argument	RCS Value	RCSVAL	Argument	RCS value adjusted for scintillation

TABLE 2.4-9. Input-Output Variables for Function EXPDRW.

FUNCTION: EXPDRW					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
MEANVL	Argument	Mean value to make exponential draw around	EXPDRW	Argument	Exponential draw
UNIRAN	Argument	Random number used to make draw			

TABLE 2.4-10. Input-Output Variables for Function CHIDRW.

FUNCTION: CHIDRW					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
MEANVL	Argument	Mean value to make exponential draw around	CHIDRW	Argument	Chi squared draw - 4th degree
UNIRAN	Argument	Random number used to make draw			

TABLE 2.4-11. Input-Output Variables for Subroutine COREL8.

SUBROUTINE: COREL8					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
OLDTIM	Argument	Previous time correlation was made	CURVAL	Output Argument	The new correlated value
OLDVAL	Argument	Previous value to make correlation from			
CURTIM	Argument	Current time to make correlation			
CURVAL	Argument	The value which needs to be correlated			

2.4.4 Assumptions and Limitations

The glint or angle noise portion of the fluctuations functional element is able to model, after making a correction in the calculation of the effective target size in azimuth, the effects for straight and level aircraft targets. However, the equations need to be modified if one wishes to model targets not in level flight.

The scintillation or amplitude noise portion of the fluctuations functional element is able to model the four Swerling cases. Specifically, it will model the statistics of complex targets such as relatively large multi-engine aircraft, as well as more generic scatterers. However, it is not designed to model the scattering from highly directive reflectors when viewed from random aspects, such as randomly oriented flat plates, corner reflectors, and antennas.